CLAIMS

What is claimed is:

1. A composite catalyst for producing synthesis gas, said catalyst comprising a mixture of at least two distinct populations of particles and said catalyst having activity for converting reactive species comprising at least one gaseous hydrocarbon and oxygen via partial oxidation to form carbon monoxide and hydrogen,

wherein a first of said populations comprises a first plurality of particles comprising at least one catalytic metal disposed on a first support, and

wherein a second of said populations comprises a second plurality of particles comprising at least one promoter disposed on a second support.

2. The catalyst of claim 1 wherein said catalytic metal is chosen from the group consisting of Rh, Pd, Ru, Os, Ir, Pt, Co, Ni, Re, and oxides thereof.

3. The catalyst of claim 1 wherein said at least one promoter is chosen from the group consisting of La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, and oxides thereof.

4. The catalyst of claim 1 wherein said catalytic metal comprises Rh and said promoter comprises Sm.

5. The catalyst of claim 4 comprising 0.05 - 25 wt% Rh and 0.1 - 10 wt% Sm (based on total weight of the catalyst).

6. The catalyst of claim 1 wherein said first and said second supports are each made using at least one material chosen from the group consisting of boehmite, pseudo-boehmite, alumina, zirconia, magnesia, titania, ceria, thoria, boria, cordierite, mullite, silica, niobia, vanadia, nitrides, and carbides.

7. The catalyst of claim 1 wherein said first and said second supports each comprise at least one material chosen from the group consisting of alumina, zirconia, magnesia, titania, ceria, thoria, boria, cordierite, mullite, silica, niobia, vanadia, nitrides, and carbides.

8. The catalyst of claim 7 wherein at least one of said first and said second supports further comprises at least one structural stabilizer selected from the group consisting of B, Mg, Si, Ca, Ti, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Se, Sr, Zr, Ba, Sc, Y, La, Ce, Nd, Pr, and Sm.

9. The catalyst of claim 1 wherein at least one of said first and said second supports includes a refractory material selected from the group consisting of aluminum oxide, zirconium oxide, titanium oxide, silicon oxide, and combinations thereof and a structural stabilizer selected from the group consisting of B, Mg, Si, Ca, Ti, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Sr, Zr, Ba, Se, Sc, Y, La, Ce, Nd, Pr, Sm, and combinations thereof.

10. The catalyst of claim 1 wherein a majority of each of said first and said second pluralities of particles have a diameter of less than 5 microns.

11. The catalyst of claim 10 wherein said majority of each of said first and said second pluralities of particles have a diameter of less than 1 micron.

12. The catalyst of claim 1 wherein said first and said second populations are mixed such that the reactive species can spillover between said at least one catalytic metal and said at least one promoter.

13. The catalyst of claim 1 wherein said catalyst comprises a plurality of distinct structures, each said structure having a maximum characteristic length of less than 6 millimeters.

14. The catalyst of claim 13 wherein each said structure has a maximum characteristic length of less than 3 millimeters.

15. The catalyst of claim 14 wherein the maximum characteristic length of each said structure is in the range of about 300 microns to about 3 millimeters.

16. The catalyst of claim 1 wherein said first and said second supports comprise the same support material.

17. The catalyst of claim 10 where the distinct structures are brought into close proximity by applying pressure to make a composite particle.

18. A catalyst comprising:

a first plurality of particles comprising a first active metal disposed on a first support material, said first active metal selected to promote the conversion of reactive species comprising oxygen and at least one light hydrocarbon via partial oxidation; and

a second plurality of particles comprising a first promoter disposed on a second support material, wherein said first and said second pluralities of particles are mixed and disposed in close enough proximity to each other to allow said reactive species to spillover between them.

19. A method for making a synthesis gas catalyst suitable to promote the conversion of reactive species comprising oxygen and at least one light hydrocarbon, the method comprising the steps of:

(a) depositing a first active metal on a first support material;

(b) depositing a first promoter on a second support material;

(c) mixing said first and said second support materials in such a way that said reactive species can spillover between said first active metal and said first promoter when said catalyst is in service and under reaction conditions.

20. The method of claim 19 wherein said first active metal comprises a metal selected from the group consisting of Rh, Pd, Ru, Os, Ir, Pt, Co, Ni, Re, and oxides thereof.

21. The method of claim 20 further comprising the step of:

(d) before step (c), depositing a second active metal on said first support material, said second active metal being selected from the group consisting of Rh, Pd, Ru, Os, Ir, Pt, Co, Ni, Re, and oxides thereof.

22. The method of claim 19 wherein said first and said second support materials each comprise a distinct plurality of particles.

23. The method of claim 22 wherein a majority of said pluralities of particles have a diameter less than 5 microns.

24. The method of claim 23 wherein a majority of said pluralities of particles have a diameter less than 1 micron.

25. The method of claim 19 wherein said first promoter is chosen from the group consisting of La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, and oxides thereof.

26. The method of claim 25 further comprising the step of:

(d) before step (c), depositing a second promoter on said second support material, said second promoter being chosen from the group consisting of La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, and oxides thereof.

27. The method of claim 19 wherein said first and said second support materials are each made using at least one material chosen from the group consisting of boehmite, pseudo-boehmite, alumina, zirconia, magnesia, titania, ceria, thoria, boria, cordierite, mullite, silica, niobia, vanadia, nitrides, and carbides.

28. The method of claim 19 wherein said first and said second support materials each comprise at least one material chosen from the group consisting of alumina, zirconia, magnesia, titania, ceria, thoria, boria, cordierite, mullite, silica, niobia, vanadia, nitrides, and carbides.

29. The method of claim 28 wherein at least one of said first and said second supports further comprises at least one structural stabilizer selected from the group consisting of B, Mg, Si, Ca, Ti, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Se, Sr, Zr, Ba, Sc, Y, La, Ce, Nd, Pr, and Sm.

30. The method of claim 19 wherein at least one of said first and said second supports includes a refractory material selected from the group consisting of aluminum oxide, zirconium oxide, titanium oxide, silicon oxide, and combinations thereof and a structural stabilizer selected from the group consisting of B, Mg, Si, Ca, Ti, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Sr, Zr, Ba, Se, Sc, Y, La, Ce, Nd, Pr, Sm, and combinations thereof.

31. The method of claim 28 wherein said first and said second support materials comprise the same material.

32. The method of claim 19 wherein said first active metal comprises Rh and said first promoter comprises Sm.

33. A method for making synthesis gas comprising the steps of:

(a) contacting a first reactive species comprising oxygen and a second reactive species comprising at least one light hydrocarbon with a catalyst at reaction conditions, said catalyst comprising:

a first active metal disposed on a first plurality of support particles; and

a first promoter disposed on a second plurality of support particles, said first and said second pluralities of support particles being mixed in such a way that said first and said second reactive species can spillover between said first active metal and said first promoter; and

(b) converting a portion of said second reactive species to form a product comprising hydrogen and carbon monoxide.

34. The method of claim 33 wherein said first active metal comprises a metal selected from the group consisting of Rh, Pd, Ru, Os, Ir, Pt, Co, Ni, Re, and oxides thereof.

35. The method of claim 34 wherein said catalyst further comprises

a second active metal disposed on said first plurality of support particles said second active metal being selected from the group consisting of Rh, Pd, Ru, Os, Ir, Pt, Co, Ni, Re, and oxides thereof.

36. The method of claim 33 wherein a majority of said first and said second pluralities of support particles have a diameter less than 5 microns.

37. The method of claim 36 wherein a majority of said first and said second pluralities of support particles have a diameter less than 1 micron.

38. The method of claim 33 wherein said first promoter is chosen from the group consisting of La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, and oxides thereof.

39. The method of claim 38 wherein said catalyst further comprises

a second promoter disposed on said second plurality of support particles, said second promoter being chosen from the group consisting of La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, and oxides thereof.

40. The method of claim 33 wherein said first and said second pluralities of support particles are each made using at least one refractory material chosen from the group consisting of boehmite, pseudo-boehmite, alumina, zirconia, magnesia, titania, ceria, thoria, boria, cordierite, mullite, silica, niobia, vanadia, nitrides, and carbides.

41. The method of claim 33 wherein said first and said second pluralities of support particles each comprise at least one refractory material chosen from the group consisting of alumina, zirconia, magnesia, titania, ceria, thoria, boria, cordierite, mullite, silica, niobia, vanadia, nitrides, and carbides.

42. The method of claim 41 wherein at least one of said first and said second supports further comprises at least one structural stabilizer selected from the group consisting of B, Mg, Si, Ca, Ti, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Se, Sr, Zr, Ba, Sc, Y, La, Ce, Nd, Pr, and Sm.

43. The method of claim 33 wherein at least one of said first and said second supports includes a refractory material selected from the group consisting of aluminum oxide, zirconium oxide,

titanium oxide, silicon oxide, and combinations thereof and a structural stabilizer selected from the group consisting of B, Mg, Si, Ca, Ti, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Sr, Zr, Ba, Se, Sc, Y, La, Ce, Nd, Pr, Sm, and combinations thereof.

44. The method of claim 41 wherein said first and said second pluralities of support particles have at least one material in common.

45. The method of claim 33 wherein said first active metal comprises Rh and said first promoter comprises Sm.

46. A method for making middle distillates from at least one light hydrocarbon comprising the steps of:

(a) contacting a first reactant comprising oxygen and a second reactant comprising at least one light hydrocarbon with a catalyst at reaction conditions, said catalyst comprising:

a first active metal disposed on a first plurality of support particles; and

a first promoter disposed on a second plurality of support particles, said first and said second pluralities of support particles being mixed in such a way that said reactants can spillover between said first active metal and said first promoter;

(b) converting at least a portion of said first and second reactants with said catalyst to form a synthesis gas comprising predominantly CO and H_2;

(c) feeding said synthesis gas to a Fischer-Tropsch process; and

(d) converting said synthesis gas into a hydrocarbon product comprising middle distillates.

47. The method of claim 46 wherein said first active metal comprises a metal selected from the group consisting of Rh, Pd, Ru, Os, Ir, Pt, Co, Ni, Re, and oxides thereof.

48. The method of claim 46 wherein said first promoter is chosen from the group consisting of La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, and oxides thereof.